PATENT SPECIFICATION

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DRAWINGS ATTACHED

1 301 004

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(54) METHOD AND APPARATUS FOR CLEANING CONTAMINATED INDUSTRIAL GASES

(71) I, Hugh Emory Gardenier, a citizen of the United States of America, of 903 Forrest Drive, Tullahoma, Tennessee, 37388, United States of America, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for cleaning contaminated gases.

Many industrial processes require the application of heat to basic materials so that the material can be melted and combined with other substances or purified and refined. Typical of this type of process is steel production and the refining of non-ferrous metallic ores. A by-product of these processes is frequently high temperature contaminated gases. For many years, these industrial waste gases have been discharged in an uncontrolled manner into the atmosphere. Since this is a major identifiable source of air pollution, considerable pressure is being exerted to prevent this type of atmospheric pollution.

Currently there are two basic approaches to the problem of handling the hot contaminated industrial gases. The first process is generally referred to as the dry filter system. The basic elements of this system are ducting, fan, filter house, and conveyor system. The basic problem with equipment of this type is the temperature limitation of the filter elements. In most instances, the gas temperature must be cooled below approximately 500°F. before it is filtered. The cooling can be accomplished by drawing atmospheric air into the ducting and mixing it with the contaminated industrial gas. This additional air required for cooling increases the size of the fan and motor necessary to draw the gases through the ducting and into the filter house. The fans employed are generally placed directly in the ducting and thus are subject to corrosion by the hot gas stream, resulting in high maintenance costs. Furthermore, fans of this type generally require up to about 4000 horsepower for operation, thereby representing a major portion of the operating costs of the system. The system works satisfactorily; however, as mentioned above, the installation cost is high, and the maintenance of the fan and filters is costly.

The second basic type of cleaning system is referred to as the wet scrubber process. The basic elements of this system are gas ducting, venturi, in-stream fan, water separator, and water filter system. With this type of equipment, the hot gases are removed from the process through the gas ducting and are passed through a venturi to increase the velocity thereof. As it passes through the venturi water is injected into the gas stream, and the contaminants are captured in the water particles. The mixture is then passed through a fan into a water separator where the clean gases discharge to atmosphere, and the contaminated water is discharged to a water cleaning system. Equipment of this type works satisfactorily; however, the installation cost in high, and the operating and maintenance costs are also very high.

The present invention seeks to provide a method and apparatus for removing contaminants from industrial gases which avoids the economic problems of high installation costs, high running costs and high maintenance costs.

The method of the present invention comprises introducing a preheated cleansing liquid into the contaminated gas stream as it flows through a duct, said cleansing liquid being introduced into said gas stream through a nozzle positioned in said duct and under conditions of temperature and pressure such that a portion of the cleansing liquid vaporises upon leaving the nozzle

[*Price 25p*]

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with concomitant atomisation of acceleration of the remaining portion of the cleansing liquid to a velocity at least 200 ft. per sec. greater than the velocity of the gas stream entering the duct, passing the contaminated gas stream, the vaporised portion of the cleansing liquid and the atomised portion of the cleansing liquid to a mixing zone located in said duct downstream from said nozzle and wherein the contaminated gas and the vaporised and atomised portions of the cleansing liquid mix with consequent entrapment of the contaminant particles in the atomised droplets of cleansing liquid and creation in said mixing zone of a region of reduced pressure, and passing the effluent mixture from said mixing zone to a gas-liquid separator in which the decontaminated gas stream is separated from the cleansing liquid and from which the decontaminated gas stream is vented.

The invention also relates to apparatus for carrying out the above method, such apparatus comprising a ducting for receiving a contaminated gas stream from a source, said ducting including a mixing section in which the contaminated gas stream may be mixed with the vaporised and atomised portions of the cleansing liquid, a gas-liquid separator connected to the ducting at the downstream end of said mixing section, a nozzle mounted in said ducting at the upstream end of said mixing section, a conduit connected to said nozzle, a pump for feeding cleansing liquid under pressure to said nozzle through said conduit, and means for heating the cleansing liquid as it flows through said conduit, said nozzle and ducting and said pump and heating means being so constructed and arranged that the cleansing liquid may be introduced into said mixing section through said nozzle as a mixed stream of vapour and atomised droplets, the latter having a velocity at least 200 ft. per sec. greater than that of the contaminated gas stream.

The method of this invention is most particularly applicable to the treatment of contaminated gas streams which are at elevated temperature, as resulting from, for example, a steel-making process or a metalliferous ore-refining process. In such cases, the cleansing liquid can be preheated by indirect heat exchange contact with the hot gas. The liquid is then introduced into said hot gas downstream of the point of heat exchange under conditions of elevated temperature and pressure such that at least a portion of said liquid is converted to vapour and the remainder is atomised and accelerated by the expansion accompanying said vapour formation, and the hot gas is then mixed with said vaporised and atomised liquid, thereby entrapping said contaminants in said atomised liquid. According to an alternative method of the present invention, the contaminated gases, when they are suitably combustible, can be ignited in the presence of additional oxygen (e.g. air) to provide heat to an indirect heat exchanger through which the cleansing liquid is passed prior to being introduced directly into the hot gas downstream of the heat exchanger. In such cases, an external source of ignition for the hot gases and air is provided, for example, by a pilot burner supplied by an exterior fuel source.

A feature of the method of the present invention is the creation in the mixing zone of a region of reduced pressure relative to the pressure in the source of contaminated gas by the introduction of a hot cleansing liquid into the contaminated gas stream under conditions effective to vaporise part of the cleansing liquid. This region of reduced pressure serves to draw the contaminated gas through the ducting past the point of introduction of the cleansing liquid and into the mixing zone, without requiring any additional gas transfer means.

According to yet another variation in the method of this invention, the stream of liquid recovered from the separator and containing said contaminants may be treated to remove the contaminants from at least a portion thereof, and at least a portion of the thus cleaned liquid may be recycled through the heat exchange means.

According to yet another variation, the mixture of vapourised and atomised liquid and gas exiting from the mixing zone may be contacted with a coolant prior to passing said separator to reduce the temperature thereof, thereby condensing at least a part of the vaporised liquid.

Many other features of the method and apparatus of the invention will be apparent from the further description made to the accompanying drawings wherein:

Figure 1 is a schematic flow diagram of a method and apparatus according to the invention as applied to the treatment of a hot contaminated gas stream;

Figure 2 is a schematic representation of one arrangement of nozzle and mixing chamber which may be used in the method and apparatus of the invention as described with reference to Figure 1;

Figure 3 is an enlarged representation of the nozzle shown in Figure 2;

Figure 4 is a schematic flow diagram showing a variation of the method described with reference to Figure 1; and

Figure 5 is a schematic flow diagram of a second variation of the method described with reference to Figure 1.

Referring to Figure 1, reference numeral 1 indicates an industrial furnace in which a process is performed which results in a hot

gas stream containing contaminants either as a primary or secondary product. Exemplary are processes in which heat is applied to basic material which is melted and combined with other substances or purified and refined, such as process for steel production, for example, processes utilizing basic oxygen steel furnaces, blast furnaces, and electric arc steel furnaces of from about 25 to greater than 200 tons of steel capacity or foundary cupolas, or the refining and purification of nonferrous metallic ores, for example, titanium, or processes for the production to glass. The contaminants contained in the hot gases produced from the above processes are particulate materials, such as metallic particles and oxides, and also gaseous contaminants of many types.

Gas ducting 2 is provided so that the hot industrial gases may be drawn away from the furnace or processing vessel. Heat contained in these high temperature gases is transferred to a liquid heat transfer medium by means of indirect heat exchanger 5. The indirect heat exchanger can be of any commercially available configuration, the surface area of which is designed for the proper liquid temperatures at the design flow rates for each particular system as is well understood by those skilled in the art. A liquid pump 4 is provided to force the liquid through indirect heat exchanger 5 at least in part from a source indicated generally as 3. The heat exchange medium can be any liquid commonly used as such and is selected from a consideration of the particular process parameters present in the system, together with the properties of the liquid, such as heat capacity, vapor pressure, etc., as will be well understood by those skilled from a consideration of the above and the following detailed description of the invention. For example, the liquid can be water, or other suitable liquid e.g. a fluorinated hydrocarbon; however, because of its availability and desirable properties, the invention will hereinafter be described with reference to water as the heat exchange medium although the medium obviously need not be limited to such.

Heat contained in the high temperature gas, which, for example, can be at a temperature in the range 200 to 3500°F., is transferred to the water through the indirect heat exchanger. The heated water flows from the indirect heat exchanger through transfer means 6 and 7 is stored for later use in the reservoir 7 or delivered by a water pump 8 directly to ejector nozzle 9, one embodiment of which is shown in greater detail in Figure 3.

Because of the relative velocity between the water droplets issuing from the nozzle and the gas contaminants, the droplets will entrap the particles carried by the gas stream. Gaseous contaminants which are soluble in the water or liquid employed will also be removed from the gas stream by mass transfer therewith, thus forming a solution with the water droplets. The velocity of the droplets is controlled by the area of the nozzle exit, the dimensions of the mixing chamber, the pressure of the water upstream of the nozzle, and the amount of water converted to vapor, and the temperature of the water. These variables can, of course, be varied within a wide range depending upon economic considerations, such as size of the equipment and the nature and temperature of the hot gas. It has been found that the droplet velocity must be at least 200 ft./sec. greater than the velocity of the gas stream. More preferably, the velocity of the droplets is at least 700 ft./sec. greater than the velocity of the gas stream.

Because of the conditions of temperature and pressure of the water, the pressure being elevated by the combined action of pumps 4 and 8, at least a portion of the water is converted to steam as it issues from the nozzle. The expansion accompanying the formation of the steam accelerates and separates the remaining water into small droplets that are thereby propelled at high velocity. In general, it is preferable to adjust the temperature and pressure of the water in relationship to the apparatus employed such that from 5 to 20 weight percent of the water issuing from the nozzle is converted to steam. For most applications, it has been found adequate to convert about 15 percent of the water to steam. Since in this relationship the temperature and pressure of the water are dependent variables, it is possible to select many sets of temperatures and pressures which will result in the required conversion of water to steam. In general, it has been found that water pressures of from 50 to 700 psia and water temperatures of from 220 to about 500°F. give best results. Of course, temperatures and pressures outside of this range may be employed.

The temperature of the hot gas, of course, limits the temperature to which the water can be efficiently raised in indirect heat exchanger 5. For gases at from 200 to 3500°F., the above parameters are applicable. For hot gases in the lower temperatures of this range, higher pressures and/or smaller nozzle areas and/or smaller mixing chamber throat areas can be employed and vice versa. Furthermore, an absolute lower limit on the water temperature is generally set at 212°F., since for temperatures lower than this reduced pressure is required to partially vaporize the water, necessitating the use of vacuum producing equipment which would substantially increase the installation and operating costs of the instant

invention. It is generally desirable to operate within the higher temperatures and pressures given above, since smaller equipment can be used therewith.

In general, the volume of water employed is not a critical parameter, but water flow rates within the range of from 1 to 3000 U.S. gal./min. are preferred. It has been found, however, that the ratio of the weight of hot gas to the total weight of water employed must be controlled to some extent. For most systems, a ratio of the weight of gas to the weight of water must be within the range 0.5:1 to 2.5:1 will give good results; with ratios in the range 1.5:1 to 2:1 being especially preferred. This system operates effectively over a wide range of contaminant concentrations. Higher water flows, of course, are necessary for systems containing higher concentrations of contaminants.

The exact size and composition of the contaminant particles is not a critical parameter of the instant invention, and it has been found that contaminant particles as small as 1 micron can be efficiently removed. According to the invention, greater than 90% of the contaminant particles can be removed; however, removal efficiencies as high as 99.95% can be achieved although at some sacrifice of process economics.

From the above, it should be clear that each individual application of this process requires an engineering analysis to determine the proper water temperature, flow rate, and pressure. The operating principle remains the same, however, regardless of the size and type of application.

The geometry of a typical nozzle and mixing chamber is shown in Figures 2 and 3, the dimensions of which are varied depending on the volume flow of gas required, type of contaminants in the gas, and the degree of cleaning necessary. It should also be noted that the ejector nozzle can be either a single nozzle similar to the one shown in the diagram, or a cluster of several nozzles as will be obvious to those skilled in the art. The water flow created by pump 8 (Fig. 1) passes through the ejector nozzle shown generally at 101. The hot gas containing contaminants passes through ducting 100 after passing over indirect heat exchanger 5 (Fig. 1). The water enters the nozzle through 200 into the throat area 202 through the expanding portion shown as 204 and the exit shown as 205. As described above, because of the temperature and pressure of the water and the apparatus dimensions, at least a portion of the water is converted to steam by exiting through the nozzle. In the venturi-shaped mixing chamber 10 shown generally in Figure 1 and in more detail in Figure 2 and comprising two end portions, the cross-sectional areas of which decrease progressively towards a centrally located throat of constant cross-sectional area, the mixture velocity produces pressure shock waves therein enhancing the mixing of the water droplets and the contaminated gas. For best results the ratio of nozzle exit area to nozzle throat area is from 1:1 to 50:1 and the ratio of mixing chamber throat area 106 to nozzle throat area 201 is from 50:1 to 1000:1.

The dimensions of the apparatus are in general a function of the temperature of the flowing gas stream. As previously stated, the quantity of water converted to steam determines in part the velocity of the droplets. The velocity of the droplets due to this phenomenon is thus a function of the available thermal energy in the flowing gas stream. For higher temperatures, the water may be heat exchanged to a higher temperature, thereby causing greater conversion to steam, all other parameters being held constant. Thus, for systems of lower thermal energy, the above area ratios are placed in the lower ranges in order to create a smaller geometry thus achieving higher velocities and vice versa.

The expansion accompanying the formation of steam as the water exits from the nozzle, the venturi effect in the mixing chamber, and the pressure shock waves created therein create a region of reduced pressure in the vicinity of the nozzle relative to the pressure in the industrial furnace or process such that a pressure differential is imposed on the system causing the gas to be sucked from the furnace or process. Thus, the system is further designed to impose the pressure differential required to remove the quantity of gas produced by the furnace or process within a broad general range, the control of the flow rate being more finely adjusted by the velocity of the liquid issuing from the nozzle.

Referring back to Figure 1, the mixture of atomized water, steam, and hot gas exiting from the mixing chamber can be optionally further contacted with a coolant. The coolant may be the same or different as the liquid used as the heat exchange medium. For most applications, it is, of course, preferred to use the same liquid for both purposes. The contacting of the coolant with the mixture is accomplished by spraying said coolant into the ducting containing the gas, for instance, through a cluster of nozzles such as shown by 11. Any configuration of nozzles commonly used for similar purposes in the industry is acceptable. In systems employing recycle of the heat exchange medium in order to conserve operating costs, it is necessary to reduce the temperature of the mixture thereby condensing at least a portion of the vaporized liquid, thereby reducing the loss of said liquid. In general, where water is employed as the heat ex-

change medium, it is preferred to reduce the temperature of the mixture to from 150 to 200°F., more preferably to 175°F. In this way, it has been found that only about 10% of the water employed remains as vapor and is thus lost to the system.

The mixture is then passed to a commercially available gas-liquid separator 12 wherein the water droplets containing the contaminants are separated from the gas stream which then may be discharged to the atmosphere through 13 or to further processing. For example, the separator can be similar to the cycle separators manufacture by the R. P. Adams Co., The Burgess Co., the Centrifix Corp., or the Raleigh-Austin Co.

The dirty water is removed from the separator through 14 and can be either discharged or passed to further treatment described below depending upon the economics of the process. The dirty water can be passed to a liquid treater shown at 15 wherein the contaminants can be removed from at least a portion of the water. The clean water is removed through transfer means 15, at least a portion of which is then recycled through pump 4 through the system, makeup water being added from the source 3 as may be required. The liquid treating apparatus can be any commercially available equipment comprising, for example, a system of filters and settling basins.

In still a further embodiment of the present invention, the gases discharged from the separator subsequent to being treated to remove contaminants can also, when they contain combustible elements, be mixed with externally supplied oxygen (e.g., air) and ignited by suitable means such as, for example, a pilot burner fueled externally, to provide combustion for a heat exchanger through which liquid is passed and subsequently introduced at a point upstream of the separator and under conditions of elevated temperatures and pressures into the hot gas.

In yet a further embodiment of the present invention, a jacket is provided around the gas ducting which conducts gas away from the furnace so that suitable cooling liquid, such as water, can be circulated around the ducting to cool the hot gas emerging from the furnace. The water or other liquid for this cooling jacket can be supplied from an external source and then, after it has performed its cooling function, added to the liquid emerging from the separator. Alternatively, the liquid used for cooling can be supplied from the liquid treater from whence it is pumped to the cooling jacket and, on emerging from the cooling jacket, can be passed through heat exchanger tubes located in the hot gas duct or returned and added to the liquid emerging from the bottom of the separator.

Referring now to Figure 4, it can be seen that a cooling jacket is provided at 306 around the gas duct 302 into which cooling liquid is introduced at 310 from the liquid treater 315 through the recycling pump 303. This liquid serves to cool the hot contaminated gas emerging from the furnace 301 and then emerges from the cooling jacket 306 at 311 where it passes to valve means 313 and in part is directed through the pump 304 to the heat exchanger 305 and then to the reservoir 307. From the reservoir, the heated liquid is pumped by the pump 308 to the ejector nozzle 309. The heat exchanger tubes 305 are heated by the combustion at 316 of the contaminant gas emerging from the furnace and mixed with air provided externally at 317 and ignited by the burner 319 which is fueled externally at 318. Liquid from the cooling jacket which is not passed through the heat exchanger 305 is returned and added to the liquid from the separator 312 at 314.

Referring to Figure 5, the treated liquid from the liquid treater 415 is pumped by means of a recycle pump 404 to the upper portion of the separator 412 and there passed through the heat exchanger 405 where the liquid is heated and passed to the reservoir 407. From the reservoir, the heated liquid is then pumped by means of the pump 408 to the ejector nozzles 409. Heating of the liquid in the heat exchanger 405 is effected by combustion of the discharged gas which is mixed with air at 416 from an external source 412 and ignited by a pilot burner 419. The pilot burner is fueled externally at 418. Cooling of the hot gases emerging from the furnace 401 is accomplished in the gas duct 402 which is surrounded by a cooling jacket 406. Water is supplied from a suitable source to the cooling jacket at 403 and emerges at 411 where it is passed into the stream of liquid emerging at 414 from the bottom of the separator 412.

Other aspects of this invention will be apparent from a consideration of the following specific example which is not intended to be limiting in any manner.

Example

In the production of steel employing an electric-arc furnace of 200 ton steel capacity, gas is discharged at about 3000°F. at a flow rate of about 130,000 cubic feet per minute. The contaminants contained in said gas include ferric oxide, dolomite, zinc, copper, and other trace metallic elements. Water is employed as the heat exchange medium, and the water pressure at the nozzle is 400 psia, the temperature is 358°F., and the flow rate is 440 gal./min. Referring to Figure 1, the

gas ducting 2 is 6 feet in diameter, and the heat exchanger 5 is a simple tube-type with nominal 1-inch diameter tubes. Referring to Figures 2 and 3, the dimensions of the mixing chamber and the nozzle are given in the following table:

Table

Reference Numeral from Figures 2 and 3	*Dimension*
100	6′
103	8′6″
104 (angle of taper)	3°
105 (" " ")	5°
106	3′
107	1′6″
108	28′6″
109	6′
110	51′9″
111	6′
200	5″
201	1″
202	4″
203 (angle of taper)	5°
204	2′2.4″
205	5.5″

The mixture issuing from the mixing chamber is contacted with additional water spray to lower the temperature to 175°F., thereby partially condensing the remaining water vapor. The mixture then flows through separator 12 wherein the clean gas is discharged through 13, and the dirty water is discharged through transfer means 14 to water treater 15. The contaminants are removed through 17, and at least a portion of the clean treated water is recycled through 16. The clean gas is thus discharged to the atmosphere.

As mentioned above, the water is discharged through the nozzle from a pressure of 400 psia into the mixing chamber such that the velocity of the water droplets formed thereby is 815 ft./sec. thereby creating a region of reduced pressure in the vicinity of said nozzle of 13 psia relative to the pressure existing in the electric-arc furnace of about 14.7 psia. This induced pressure differential of 1.7 psia causes the gas to flow from said furnace at the above rate of 130,000 cubic ft./min. which is thus equal to a gas velocity in the vicinity of said nozzle of 150 ft./sec. The water droplets thus travel at a velocity of 665 ft./sec. greater than the velocity of the gas contaminants, thereby entrapping the contaminants carried by the gas stream such that the gas discharged to the atmosphere contains less than about 10% of the contaminants contained therein before treatment.

WHAT I CLAIM IS:—

1. A method for the removal of contaminant particles from a contaminated gas stream, which comprises introducing a preheated cleansing liquid into the contaminated gas stream as it flows through a duct, said cleansing liquid being introduced into said gas stream through a nozzle positioned in said duct and under conditions of temperature and pressure such that a portion of the cleansing liquid vaporises upon leaving the nozzle with concomitant atomisation and acceleration of the remaining portion of the cleansing liquid to a velocity at least 200 ft. per sec. greater than the velocity of the gas stream entering the duct, passing the contaminated gas stream, the vaporised portion of the cleansing liquid and the atomised portion of the cleansing liquid to a mixing zone located in said duct downstream from said nozzle and wherein the contaminated gas and the vaporised and atomised portions of the cleansing liquid mix with consequent entrapment of the contaminant particles in the atomised droplets of cleansing liquid and creation in said mixing zone of a region of reduced pressure, and passing the effluent mixture from said mixing zone to a gas-liquid separator in which the decontaminated gas stream is separated from the cleansing liquid and from which the decontaminated gas stream is vented.

2. A method according to claim 1, wherein a coolant liquid is introduced into the mixture leaving the mixing zone and prior to entry into the gas-liquid separator.

3. A method according to claim 2, wherein the coolant liquid is the same as the cleansing liquid.

4. A method according to claim 1, 2 or 3, wherein the cleansing liquid, and coolant, if used, is water.

5. A method according to claim 4, wherein the cleansing liquid is preheated to a temperature in the range 220-550°F and is passed to the nozzle at a pressure in the range 50 psia to 700 psia.

6. A method according to claim 4 or 5, wherein the flow rate of cleansing liquid through the nozzle is in the range 1-3000 U.S. gallons per minute.

7. A method according to claim 4, 5 or 6, wherein the weight ratio of gas to cleansing liquid is in the range 0.5:1 to 2.5:1.

8. A method according to claim 7, wherein said ratio is from 1.5:1 to 2:1.

9. A method according to any one of claims 4-7, wherein from 5-20 per cent by weight of the cleansing liquid, based on the total weight of cleansing liquid, is vaporised upon issuing from said nozzle into the stream of contaminated gas.

10. A method according to claim 9, wherein about 15% by weight of cleansing

liquid is vaporised on issuing from said nozzle.

11. A method according to any one of the preceding claims, wherein the atomised portion of the cleansing liquid is accelerated, on leaving the nozzle, to a velocity at least 700 ft. per sec. greater than the velocity of the contaminated gas stream.

12. A method according to any one of the preceding claims, wherein a stream of cleansing liquid is withdrawn from said gas-liquid separator, reheated under pressure and recycled to said nozzle.

13. A method according to any one of the preceding claims, wherein the contaminated gas stream contains a combustible gaseous component and wherein the decontaminated gas stream from the gas-liquid separator is ignited.

14. A method according to claim 13, wherein the combustion of the decontaminated gas stream is maintained by a pilot burner supplied by an external fuel supply.

15. A method according to claim 13 or 14, wherein the cleansing liquid is preheated by indirect heat exchange with the combustion products produced by combustion of the decontaminated gas stream from the gas-liquid separator.

16. A method according to any one of the preceding claims, wherein the contaminated gas stream is at an elevated temperature and wherein the cleansing liquid is preheated by indirect heat exchange with the contaminated gas stream upstream from said nozzle.

17. A method according to any one of the preceding claims, wherein the contaminated gas stream is at a temperature in the range 200-3500°F.

18. A method according to claim 16, or 17, wherein the hot contaminated gas is cooled upstream from said nozzle by indirect heat exchange contact with a cooling liquid.

19. A method according to claim 18, wherein the coolant liquid is the same as the cleansing liquid and wherein at least a portion of the coolant liquid, after the indirect heat exchange contact with the hot contaminated gas, is brought into indirect heat exchange contact with the hot contaminated gas for the second time, and then passed to the nozzle for introduction into the contaminated gas stream.

20. A method according to any one of the preceding claims, wherein the contaminated gas stream contains a combustible component and wherein the contaminated gas stream is ignited upstream from said nozzle.

21. A method according to claim 20, wherein the combustion of the contaminated gas stream is maintained by a burner fed from an external fuel source.

22. A method according to any one of the preceding claims, wherein the contaminated gas stream is a waste or by-product from a steel-making process or a metalliferous ore-refining process.

23. A method according to claim 1, substantially as hereinbefore described with reference to the accompanying drawings.

24. Apparatus for carrying out the method of claim 1, comprising a ducting for receiving a contaminated gas stream from a source, said ducting including a mixing section in which the contaminated gas stream may be mixed with the vaporised and atomised portions of the cleansing liquid, a gas-liquid separator connected to the ducting at the downstream end of said mixing section, a nozzle mounted in said ducting at the upstream end of said mixing section, a conduit connected to said nozzle, a pump for feeding cleansing liquid under pressure to said nozzle through said conduit, and means for heating the cleansing liquid as is flows through said conduit, said nozzle and ducting and said pump and heating means being so constructed and arranged that the cleansing liquid may be introduced into said mixing section through said nozzle as a mixed stream of vapour and atomised droplets, the latter having a velocity at least 200 ft. per sec. greater than that of the contaminated gas stream.

25. Apparatus according to claim 24, wherein the mixing section of the ducting has a cross-sectional area less than that of the cross-sectional area of the ducting upstream therefrom.

26. Apparatus according to claim 25, in which the mixing section comprises end portions having cross-sectional areas which progressively decrease towards a centrally located throat portion of constant cross-sectional area.

27. Apparatus according to claim 24, 25 or 26, wherein the nozzle comprises a throat and exit portion leading from said throat.

28. Apparatus according to claim 27, wherein said exit portion is of progressively increasing cross-sectional area in a direction away from said throat.

29. Apparatus according to claim 27 or 28, as dependent on claim 26, wherein the ratio of the areas of the throat of the mixing section to the throat of the nozzle is in the range 50:1 to 1000:1.

30. Apparatus according to any one of claims 24-29, wherein the gas-liquid separator is connected to an exit duct for the separated, decontaminated gas stream, there being mounted in said exit duct a burner for igniting combustible components in said decontaminated gas stream.

31. Apparatus according to claim 30, wherein the heating means for the cleansing liquid comprise an indirect heat exchange

means mounted in said exit duct for indirect heat exchange contact with the combustion products from the decontaminated gas stream.

32. Apparatus according to any one of claims 24-29, wherein the heating means for the cleansing liquid comprise an indirect heat exchange means mounted in the ducting upstream of said mixing section for indirect heat exchange contact with the contaminated gas stream, being a hot contaminated gas stream.

33. Apparatus according to claim 31 or 32, wherein said indirect heat exchange means comprise a coil mounted in said exit duct or said ducting, respectively, and connected to said cleansing liquid conduit.

34. Apparatus according to any one of claims 24-33, wherein the ducting is provided with a cooling jacket upstream from said mixing section for the flow of a coolant therethrough.

35. Apparatus according to claim 34, as dependent on claim 32 or 33, wherein said cooling jacket is connected to the conduit for the cleansing liquid and in series with the indirect heat exchange means.

36. Apparatus according to any one of claims 24-36, including a reservoir for the heated cleansing liquid connected to said conduit downstream from the heating means.

38. Apparatus according to any one of claims 24-37, including a recycle conduit connected between said gas-liquid separator and said cleansing liquid conduit downstream from the heating means for the recycle of separated cleansing liquid.

39. Apparatus according to claim 24, substantially as hereinbefore described with reference to the accompanying drawings.

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SHEET 1

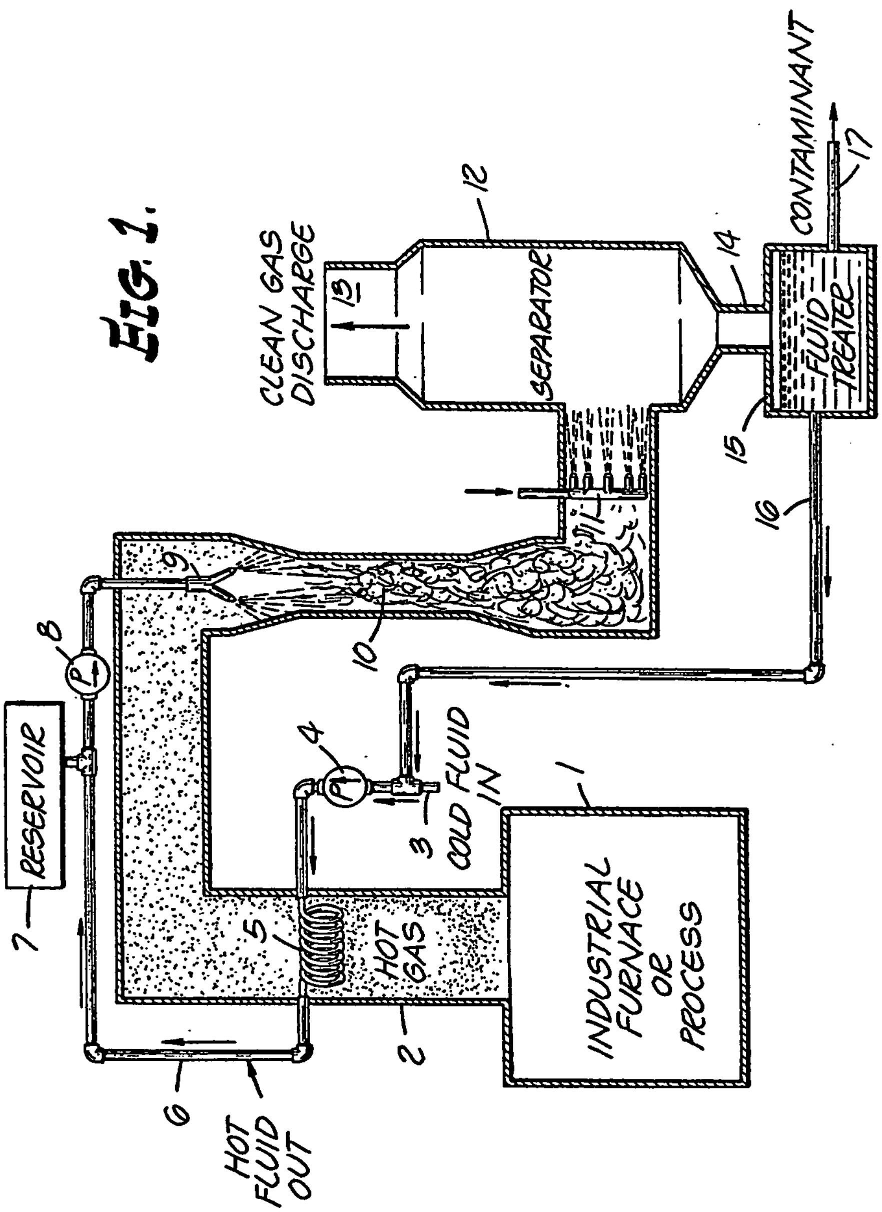

FIG. 1.

1,301,004 COMPLETE SPECIFICATION
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SHEET 2

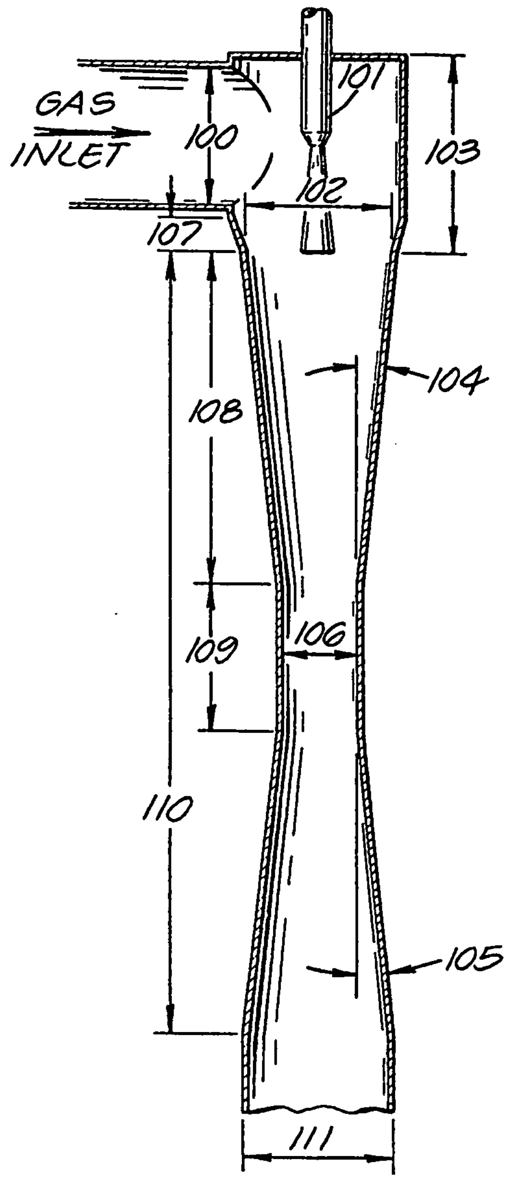

FIG. 2.

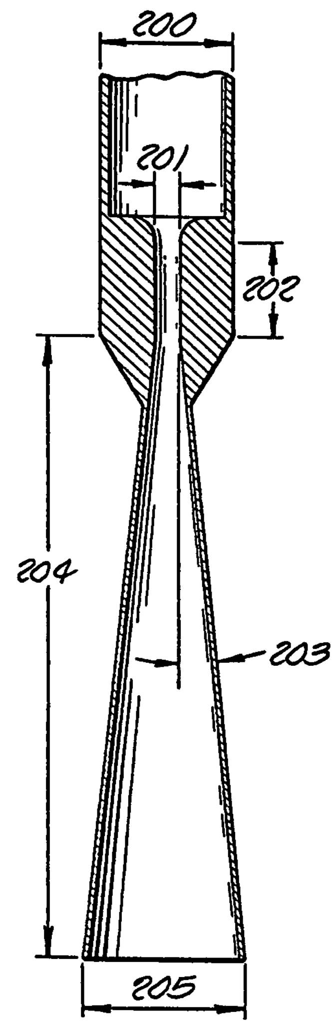

FIG. 3.

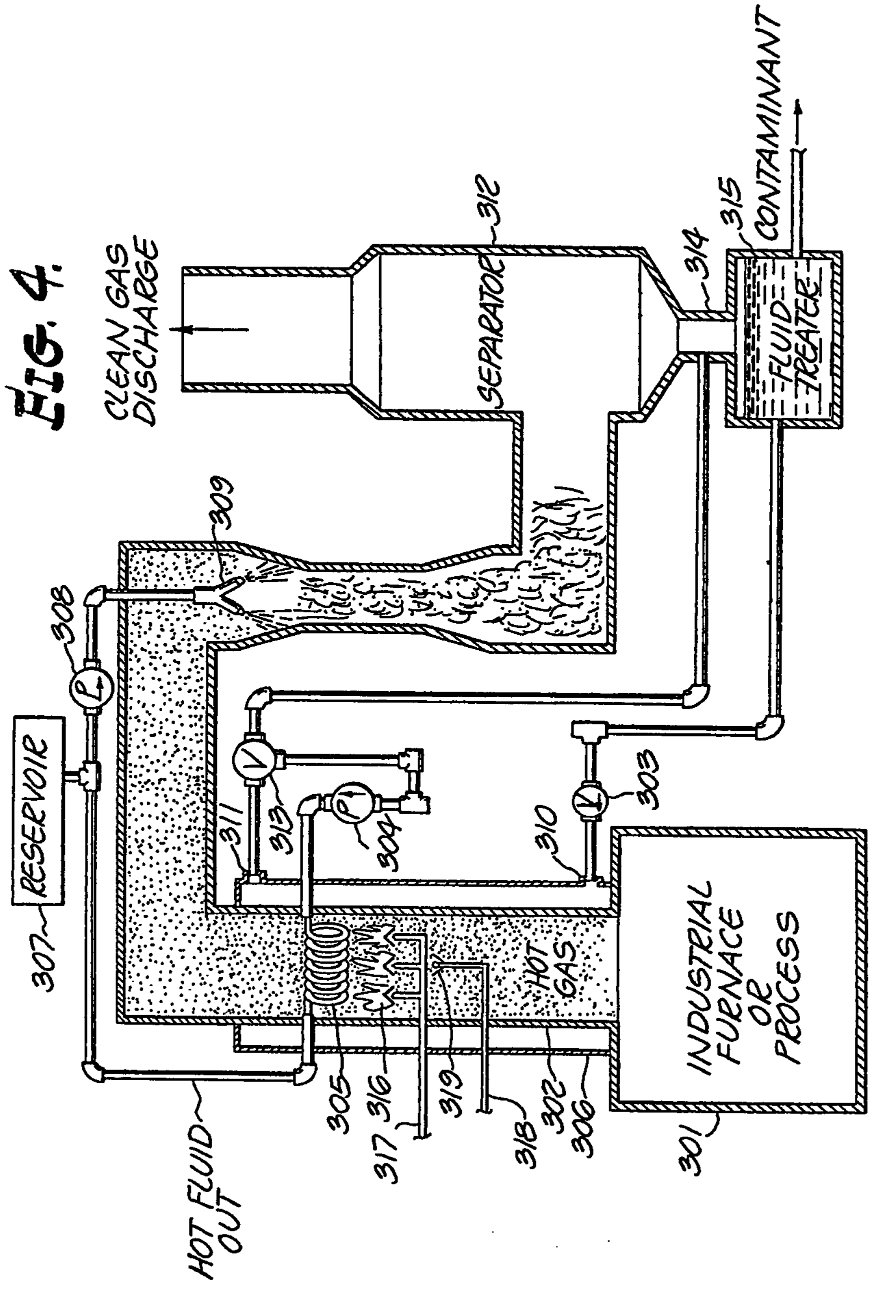
CLEAN GAS DISCHARGE
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FIG. 4.

1,301,004 4 SHEETS

COMPLETE SPECIFICATION
This drawing is a reproduction of the Original on a reduced scale.
SHEET 4

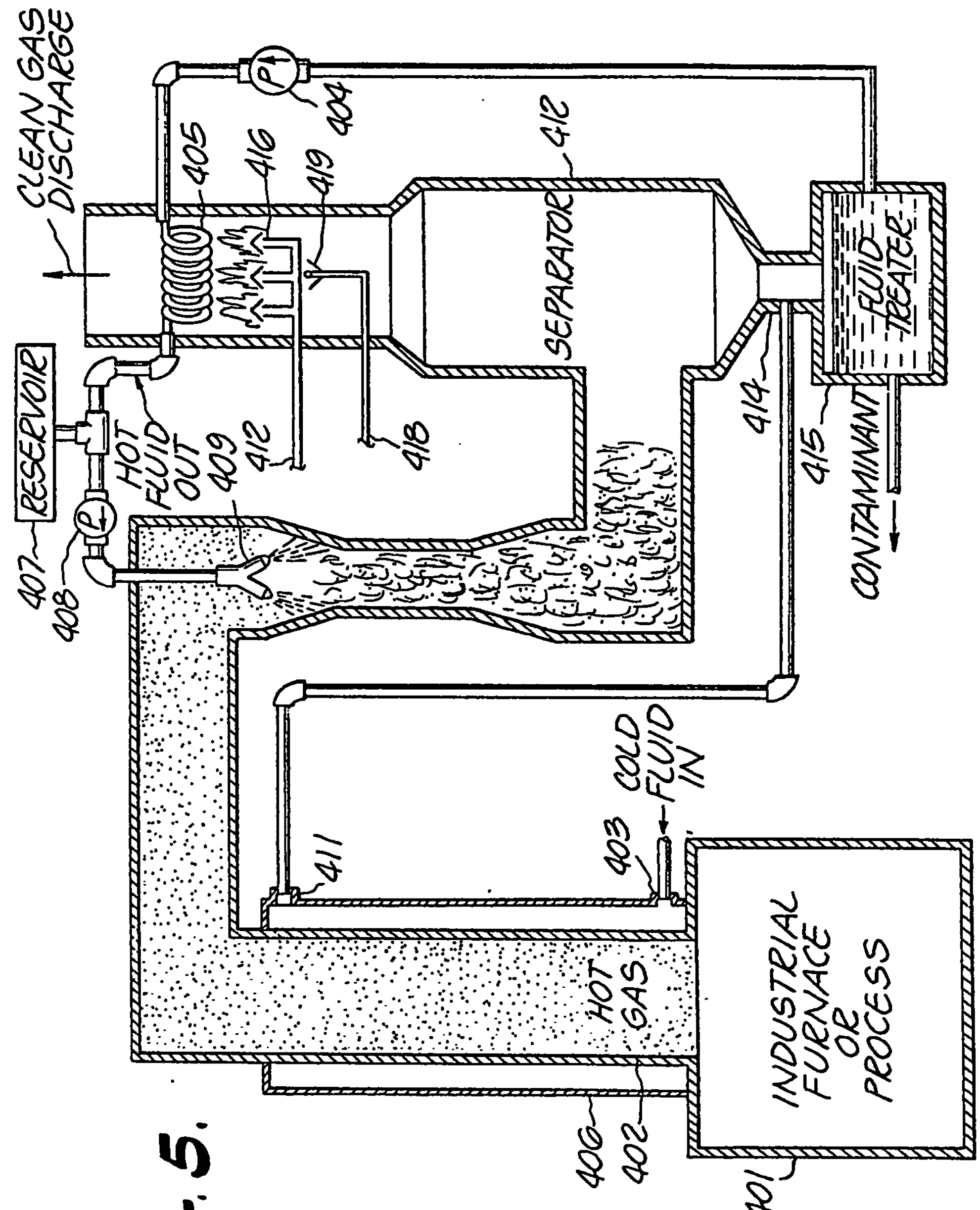

FIG. 5.

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